RESEARCH DEPARTMENT

THE EFFECTS OF HUMIDITY ON REVERBERATION ROOM MEASUREMENTS OF ABSORPTION COEFFICIENT AT HIGH FREQUENCIES

Report No. B-069

(1959/4)

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SUMMARY

An investigation has been carried out to find the reasons for the variability in the results of absorption coefficient measurements at high frequencies in the reverberation room. After elimination of random experimental errors, it appeared that the variations could be due to inaccurate corrections for changes with humidity of the absorption by the air, or to changes in the absorber itself with humidity. It is concluded that the first of these causes is the more important.

1. INTRODUCTION

In the course of reverberation room measurements of the absorption coefficients of sound absorbers, it has been found that errors of measurement can occur, at frequencies above 4 kc/s, of far greater magnitude than those found at lower frequencies. The consistency of measurements at these frequencies is poor, and various anomalous results have been obtained for sound absorbers of similar design. For example, in the tables of absorption coefficients in current use in the department, the absorption coefficient at 8 kc/s for 5% perforated hardboard covering 1" thick bitumen bonded glass silk is recorded as 0·01; the coefficient for 5% hardboard over 1" "semi-rigid" rockwool is recorded as 0·27; and the coefficient for the same cover over 1" Cabot's Quilt is 0·38. Such a wide variation is not consistent with the small differences in the measured flow resistance of the three materials.

The absorption coefficient of a material is derived from measurements of reverberation time of the reverberation room with and without the sample present. The total absorption of the room in the two conditions is calculated from the reverberation times, the difference between these two quantities, in the absence of other changes in the room, being the absorption contributed by the sample.

Experience has shown that errors in the measuring equipment may be discounted. In particular, with the commonly used oscilloscope method of measurement of reverberation time[1] the systematic errors do not change appreciably with frequency, and can be checked by recalibration at any frequency. Moreover, such errors will affect the calculated values of absorption both with and without the sample; the errors will be in the same sense for both conditions, and therefore the required difference between the two absorption figures will be subject to a small error only. Instrumental errors do not therefore explain the increased variations at high compared with low frequencies.

In a reverberation room of normal dimensions there is, however, a large amount of residual absorption at high frequencies, most of which is due to attenuation in the air itself. This varies with temperature and humidity.[2] Errors might therefore be introduced by one of several causes, which will now be examined.

2. SOURCES OF ERROR IN MEASUREMENTS AT HIGH FREQUENCIES

2.1. Errors in the Subtraction of Nearly Equal Quantities

Since the absorption coefficient is derived from the difference between two large numbers, small percentage errors in either will result in large percentage errors in the difference. Such errors may be reduced by using larger sample areas, although this is not always possible for economic reasons. A series of measurements was made using 144 ft^2 (13·4 m^2) samples instead of the usual 96 ft^2 (8·9 m^2) sample area, but large variations in measured high-frequency absorption were again found when measurements were repeated after a period of months. It would seem that although the use of small samples is bound to be a contributory source of error, it is not the prime source.

2.2. Errors Arising from the Measurement of Short Reverberation Times

It is possible that errors might arise in the measurement of short reverberation times due, for instance, to the steep slope of the decay curve. The high-frequency results could be expected to be most affected since the reverberation time of most reverberation rooms diminishes rapidly with increase of frequency. There are two reasons, however, for rejecting this hypothesis. First, it was found, in a recent investigation of the random variations in reverberation time measurement, that variability did not increase as the mean reverberation time decreased. Secondly, if we consider the consistency between individual readings obtained by different observers measuring identical decays, we find that the low-frequency results are more variable than those at high frequencies, although the low-frequency reverberation times are generally longer.

2.3. Changes of the Sample with Temperature and Humidity

The absorption coefficient of a porous absorber may vary with temperature and humidity because of variations of porosity, which could be caused by expansion or contraction of the fibres or binding material with changes of moisture absorption. The temperatures in the reverberation rooms are controlled within the limits of 62°F and 68°F but the humidity can vary from 30% to 70%. The effects of such atmospheric changes on the material itself will shortly be investigated, but allowances must first be made for all other sources of error.

2.4. Changes in Air Absorption due to Temperature and Humidity

The corrections applied for changes in air absorption with humidity between measurements may not be correct. Various sources of published information on this subject disagree; some of the discrepancies encountered will now be discussed.

The relative humidity of the Nightingale Square reverberation rooms frequently varies between 40% and 60% and occasionally does so over a period of a few days. The practice in Research Department has been to note the percentage humidity at the time of measurement, and to correct for changes that have taken place between the "empty room" and "room with sample" measurements, using Knudsen's published data.[3] The difference between a correction based on Knudsen's data and one based on that of Evans and Bazley of the National Physical Laboratory[4] for a change of humidity from 40% to 60%, is some 20 ft² (1·9 m²) units at 8 kc/s. With a typical sample area of 100 ft² (9·3 m²) the calculated values of absorption coefficient would differ by 0·20 depending upon the data used. For example, the 8000 c/s absorption coefficient of a 100 ft² (9·3 m²) sample might be calculated as 0·50 using the data of Evans and Bazley to correct for a change between measurements from 40% to 60% relative humidity. The use of Knudsen's data would yield a figure of 0·30 for this change, or 0·70 for a change in the reverse direction. It is feasible for such a change of humidity to occur in practice and it is indeed quite common for changes of the order of 15% relative humidity to occur between measurements. It is therefore evident that very large discrepancies in absorption coefficient measurement are likely to arise because of the differences between the two sets of published data. These differences of data have much less significance when applied to studio reverberation time calculations, since these do not involve the difference between two large numbers varying with humidity. The molecular absorption at 8000 c/s and 50% relative humidity differs in the two sets of data by 6%. This represents a change from approximately 26 to 28 ft² units per 1000 ft³ (8·7 to 9·3 m² per 1000 m³) of studio volume.

In view of the wide discrepancies between the two sets of published data, it was decided to make independent measurements of the effects of humidity on the attenuation of sound in air.

3. INVESTIGATION OF THE EFFECTS OF HUMIDITY ON ATTENUATION OF SOUND IN AIR

As a preliminary investigation, a short series of measurements was made to examine the change of reverberation time with change of humidity in the large reverberation room at Nightingale Square. The prevailing weather conditions allowed measurements to be made with the relative humidity as low as 32%. To obtain high humidity readings, artificial means were used; the floor was sprayed with water and the air in the room intermittently agitated. Reverberation measurements were delayed until several hours after all signs of moisture on the floor had disappeared, to allow conditions to become stabilized. No special precautions were taken to control or record the ambient temperature, the thermostatically controlled heaters being relied upon to maintain the temperature within ± 3° C. Relative humidity readings were taken from a Negretti and Zambra hygrometer mounted on one of the walls. Warble-tone pulses were injected at 4000 c/s, 5600 c/s and 8000 c/s, and the standard oscilloscope reverberation-measuring technique was used. Ten measurements were made at each frequency, each measurement being made with one of the combinations of two loudspeakers and five microphones in fixed positions. The results are shown in Figs. 1 and 2. The total absorption in the empty room is plotted.

The results obtained show close agreement with those of Evans and Bazley and diverge widely from those of Knudsen. It is evident therefore that pending any more thorough work to supplement the present measurements, the Evans and Bazley results should be used as a basis for all reverberation room corrections.

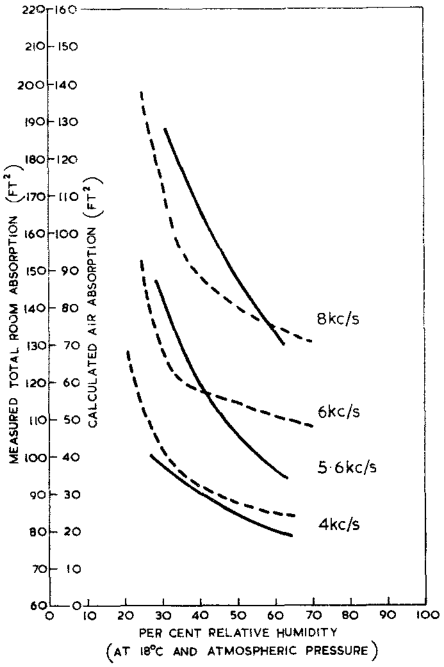

Fig. 1 - Measured absorption in empty room (3000 ft³) compared with air absorption predicted from the data of Knudsen and Harris

——— measured absorption
– – – – predicted air absorption

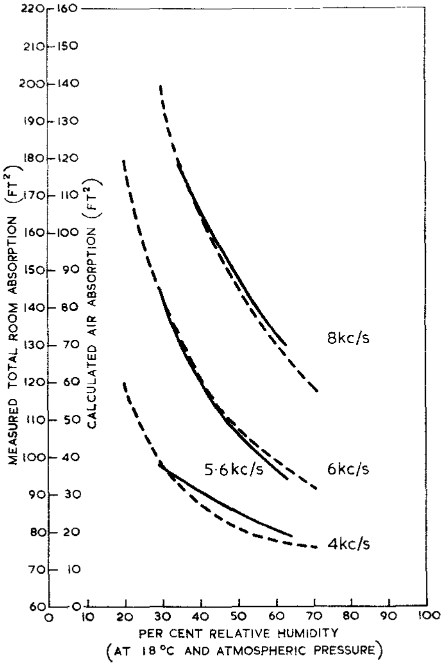

Fig. 2 - Measured absorption in empty room (3000 ft³) compared with air absorption predicted from the National Physical Laboratory data

——— measured absorption
– – – – – predicted air absorption

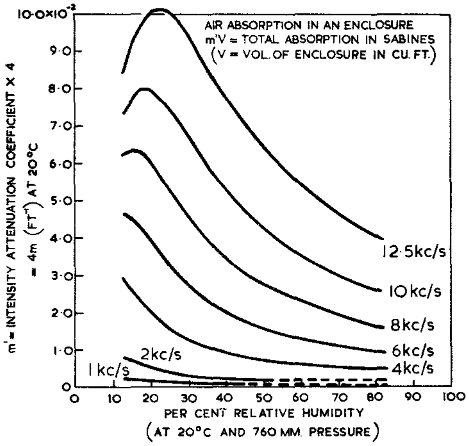

Fig. 3 - Variation of air absorption with humidity. Curves drawn from National Physical Laboratory data.

4. CONCLUSIONS

In this investigation, the influence of random experimental variations and systematic errors in the measuring apparatus have been shown to be insufficient to explain anomalous high-frequency absorption results.

Consideration of the humidity changes which can occur during the progress of an experiment and of the discrepancies between two sources of published data on air absorption shows that faulty corrections for humidity changes could well account for the observed anomalies.

A limited set of measurements of air absorption for a range of humidities shows that the data of Evans and Bazley (Fig. 3) is more reliable than that previously used in Research Department. It will therefore be used in future.

It is not necessary to assume changes in the absorption coefficient of materials with humidity to account for the anomalies, but evidence on this question may appear when the more accurate corrections for air absorption have been in use for a further period.

5. REFERENCES

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